Passive Solar

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Passive Solar

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Introduction

A home with passive solar features uses the sun's energy for space heating. This booklet explains how passive solar heating works and gives basic rules of thumb that are sensitive to Alberta's climate and latitudes. You will not be able to actually design passive solar features after you have read this booklet - there is a shelf-full of information you need for that - but you will be able to tell a designer or architect more clearly how you want to use passive solar heating in your home, and have more of a hand in the process of design.

The booklet is divided into three parts. The first section defines what we mean by passive solar heating and is followed by rules of thumb for passive solar design. The final section applies these guidelines to two examples.

The starting point for passive solar design is an energy efficient house. You have to reduce the amount of energy your home needs before the sun can make a significant contribution to your space heating. Improving the energy efficiency of your home also makes economic sense: it is the cheapest first step you can take to lower your utility bills. This booklet assumes that if you are considering passive solar features, you are already planning to build or renovate to energy efficient standards. In a new home, this means a well-sealed building with balanced centralized ventilation and insulation levels of RSI 5 to 5.25 (R 28 to 30) in the walls, RSI 7 to 8.75 (R 40 to 50) in the ceiling, and RSI 3.5 (R 20) in the basement. In a renovated home, it means coming as close to these guidelines as possible.

A home designed for the sun has lower utility bills than other homes and lots of daylight. Many passive solar homes in Alberta are heated almost exclusively with the sun. Taking advantage of the sun, however, is only one of many priorities you should have when you design or renovate your home. Your home should be most of all a place where you like to live. No amount of good passive solar design will make you feel better about a poor view from your picture window, an interior finish you do not like, or a floor plan that does not give you enough privacy. Design your home for comfortable living first - to suit your family's tastes, use of space, and work and play habits - and then adapt solar features to the plan.

What is Passive Solar Heating?

Solar heating, whether active or passive, has three key elements: a way to capture heat from the sun, a way to distribute the heat, and a way to store it if necessary. In passive solar heating, these elements are part of the home and can function without mechanical assistance. Fans and controls can enhance the performance of a passively heated space, but they are not necessary.

By contrast, active solar heating uses special solar collectors and stores the sun's energy separately from the space requiring heat. It needs pumps or fans to move heat to the space. Without this mechanical assistance, no heat would be delivered. Compared to passive solar heating, active solar is not as good an option for space heating in Alberta because it is more complicated and expensive.

As Figure 1 illustrates, a passive solar space can gain heat from the sun either directly or indirectly. A direct gain system uses features of the space itself - windows, walls and floors, for example - to collect and distribute the sun's energy. An indirect gain system uses a special heat-absorbing object, such as a concrete wall, between the sun and the space requiring heat. Indirect gain is less efficient in our climate than direct gain, but it has some advantages. The heat-absorbing object blocks sunlight from the solar-heated space and reduces glare and fabric fading.

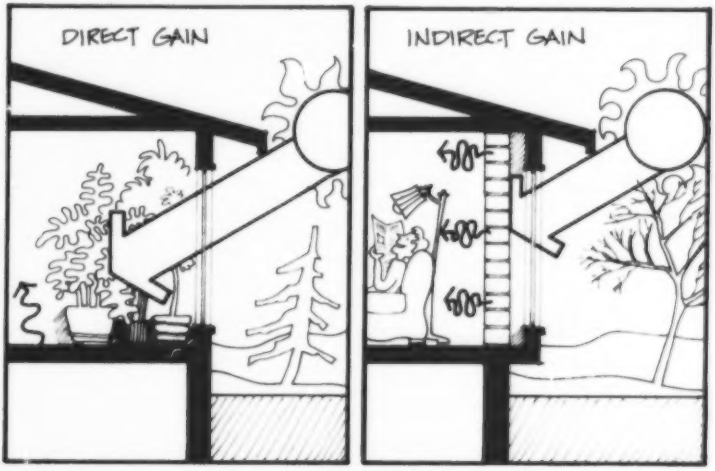

Figure 1 Types of passive solar gain.

Attached greenhouses combine the principles of direct and indirect gain. The greenhouse itself is a direct gain space but it acts like an indirect gain system when it is used to heat a house. The sun's heat is passed from the greenhouse to the house, rather than accumulating in the house directly.

In a direct gain passive solar space, windows oriented toward the sun capture the sun's energy. Sunlight enters a window, strikes objects, and is converted into heat. Since glass transmits sunlight better than heat, heat builds up behind the window in a process known as the greenhouse effect. Passive solar heating, however, involves more than adding windows to the solar side of your house. For example, the area of the windows should balance the energy needs and heat-storing capacity of your home. Your home should be well insulated and well sealed to take best advantage of heat from the sun. Your heating and ventilating systems should be designed to help circulate solar-heated air. Passive solar heating requires a well-balanced system of elements.

Rules of Thumb for Passive Solar Design in Alberta

Well-designed passive solar features take into account all the details of your site and house plan: for example the windbreaks; the heat-absorbing characteristics of building materials; the solar gains through windows on an hour-by-hour basis; and passageways and obstacles to air movement. The rules of thumb presented in this booklet are things to consider when designing passive solar features in Alberta, but a detailed design is needed to give you a system that really works well for your site and your house plan.

The process of designing passive solar features falls into three broad steps: getting sunlight into your house so that it can be used for heat; distributing the heat around the house; and incorporating materials to store heat if necessary. The following rules of thumb describe what would be best for passive solar design, all else being equal. When other considerations enter - such as comfort, esthetics and cost - the rules have to bend.

Letting the Sun In

Shape, orientation, siting and window design all affect how much sunlight enters your home.

Shape

In our climate, the best house shape is a compromise between least heat loss and most solar gain. To control heat losses, you need to minimize the exterior surface area of your house; the farther you deviate from a square floor plan, the more exterior wall you will have for the same floor area. To boost solar gains, you need to maximize the size of your south-facing wall; for the same floor area, a rectangle on an east-west axis gives you a bigger south-facing surface. A moderately elongated shape is the best compromise for prairie climates.

Shape is not a big factor in passive solar performance. The penalty for choosing a more complicated and interesting floor plan, within reason, is small.

Orientation

Whether you are building a home or adding a sunspace, most of your glass should face south. (Note that the south indicated on a compass, or magnetic south, is west of true south in Alberta. Your designer or architect should correct for this error, which varies widely across the province,when designing your home or renovation.) At our latitudes, the winter sun keeps to the southern part of the sky. It rises and sets in the southeast and southwest and stays low on the southern horizon. During the heating season, windows facing due south consequently get the most light, but up to 90 per cent of this light is available within 30 degrees east or west of due south (Figure 2). The penalty becomes greater the farther from south you vary, as shown in Table 1. Houses oriented east of south have the advantage of warming up more quickly in the morning; houses oriented west of south stay warm longer into the evening and tend to overheat from low afternoon sun angles in late spring and early fall.

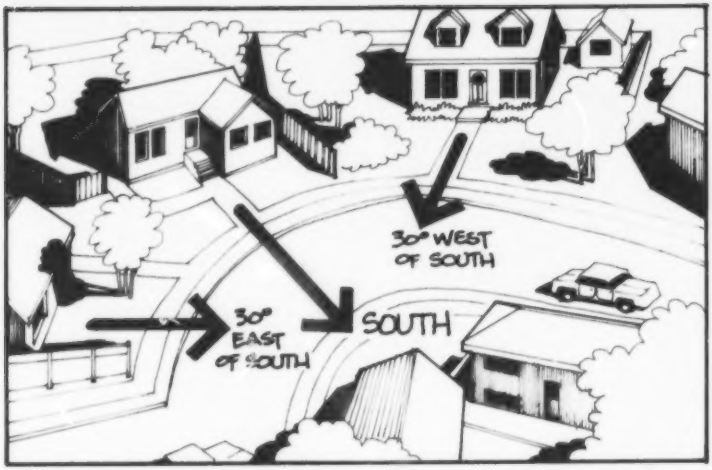

Figure 2 South-facing windows get the most light, but 90 per cent of this light is available within 30 degrees east or west of due south.

Table 1
Amount of sunlight on windows in various orientations (for 52 degrees latitude, October to April)

Orientation	% south-facing light
S	100%
SW	74%
W	32%
NW	10%
N	8%
NE	10%
E	32%
SE	74%

Windows facing southeast and southwest get the most sun in summer. The summer sun rises north of east, sets north of west, and makes an arc tipped a little to the south. For long periods of the day, the sun has access to windows facing east and west, and especially southeast and southwest. Skylights will also get a great deal of sun. If you use a lot of skylights or place many windows east or west of south, shade them during the summer to prevent overheating.

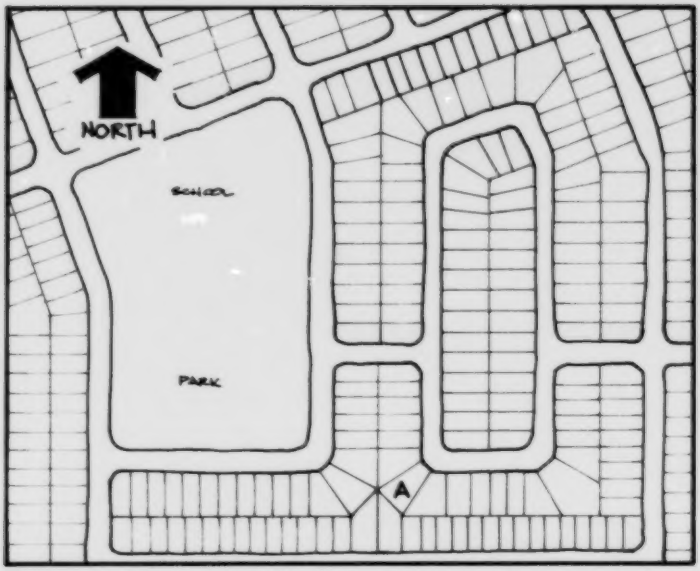

Figure 3 The best solar lots have a north-south axis or have an exposed south side.

Siting

Choose a site that will give your home access to the sun. In an urban setting, this means choosing a lot that faces either north or south so that the solar side of your home faces the street or the backyard, not the wall of your neighbor's house. Figure 3 highlights good solar lots in a typical new subdivision.

Siting a house on an urban lot is complicated by regulations that restrict how close to the front, back and sides of your property you can build. Particular lots may have other restrictions: for example, how high you can build and where you can put windows. Check these restrictions with your municipal building permits office before you buy a lot.

Make sure trees and buildings do not block the sun from the windows you want to use for solar gain. During the heating season, the sun delivers over 90 per cent of its energy between 9:00 a.m. and 3:00 p.m. These are the critical times to keep your solar-facing windows free of shadow, as Figure 4 illustrates.

On an urban lot, be careful of shading from adjacent houses as well as facing houses. Neighboring houses that extend past the solar side of your house may block the morning and afternoon sun.

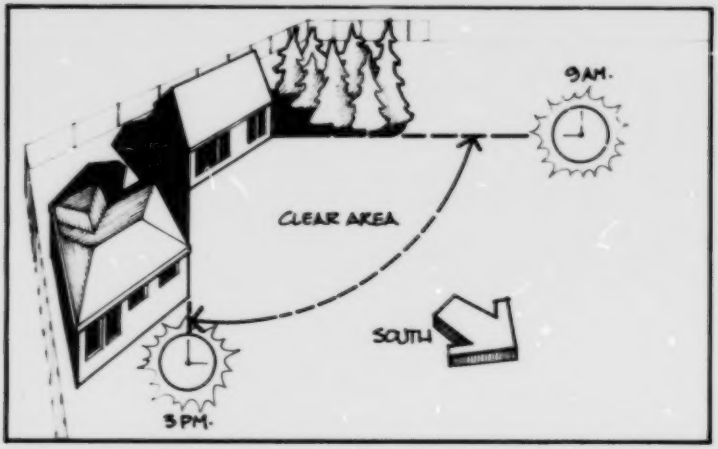

Figure 4 Ninety per cent of the sun's energy is delivered between 9:00 a.m. and 3:00 p.m.

Site your house to use trees, hills, and existing buildings as windbreaks on the windward side. It is particularly easy to take advantage of these opportunities on a rural lot where there are fewer siting regulations.

Window design

Windows are the critical element in passive solar heating. Their orientation, number and type of panes, size, shading and slope all affect the amount of heat your house gains from the sun.

Orientation and glazing for solar-facing windows. Windows both gain and lose heat. They gain heat according to how much sunlight enters them. This is determined by their orientation and by their number and type of glazings. A glazing is a single layer of transparent material such as glass, plastic or film. The greater the number of glazings, the less light penetrates. Windows lose heat according to their area and their insulation value. As area increases, heat loss increases. As insulation value increases, however, heat loss decreases. The insulation value of a window is determined mainly by its number and type of glazings: the more glazings, the higher the insulation value. Single pane windows thus admit the most light but have the lowest insulation value. In our climate, double-pane glass is a minimum, not only to control heat loss but also to prevent severe condensation and icing on windows. The booklet **Windows,** in this series, describes the advantages and disadvantages of a variety of glazings.

To contribute heat to your home, windows have to gain more heat than they lose. In other words, they must have a positive **net heat gain.** Figure 5 shows how orientation and type of glazing affect the net heat gain of windows during an Alberta heating season. Values above zero on the chart mean gains are greater than losses and the window is helping to heat the house.

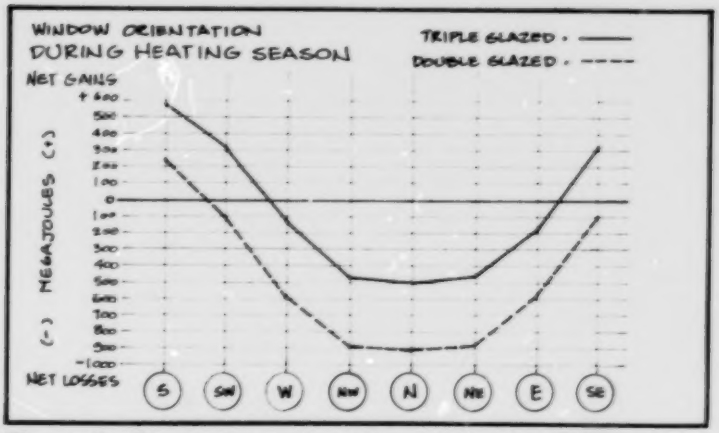

Figure 5 Comparison of net heat gains for different types of glazing.

Net heat gains are higher for triple-pane than double-pane windows in our climate. Over the course of the heating season, south-facing triple-pane windows will contribute more than twice the net heat that double-pane windows will contribute in the same orientation. Triple glazing converts southeast and southwest windows from net heat losers to net heat gainers and dramatically reduces the heat loss of other windows. Standard low-emissivity windows (double-pane windows that have a special insulative coating) have similar insulation values to triple-pane windows but admit about 10 per cent less light.

The sun is an important source of light for your home as well as a heat source. If most of your windows face one way for solar gains, how does that affect the amount of daylight in the rest of your house? The Alberta Building Code ensures adequate daylight by specifying minimum window-to-floor-area ratios that each room in your home must meet. Windows in the east, north, and west walls will help provide adequate light in each area but will increase heat losses. Clerestory windows and skylights are another way to increase daylight. Since they can face south, they can increase daylight with less heat loss (Figure 6). Clerestories are a better

option than skylights because they let in more winter sun and are easier to shade in summer. Too many south-sloping skylights can cause overheating in summer.

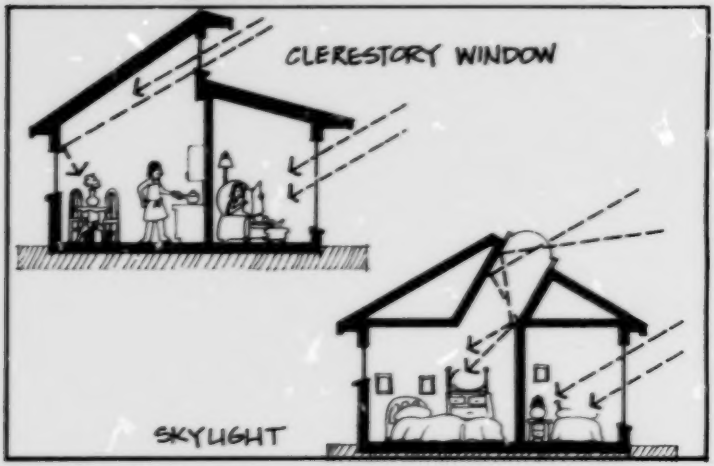

Figure 6 Options for providing daylight to a home.

Sizing solar-facing windows. Solar-facing window area is usually expressed as a percentage of floor area, where the floor area includes direct-gain spaces and rooms that open on to them. (Unless a basement has more than one or two small windows, its area is not usually counted.) For every house, there is an optimum area of south-facing glass that will result in the lowest possible heating bill. This optimum area depends on the energy efficiency of the house, its mass, and the level of glazing on south-facing windows. Though optimum from an energy cost perspective, this area may cause your home to overheat, especially on spring and fall days when the weather can be warm but the sun is still low on the horizon. Make sure your architect or designer takes this into account when sizing your solar-facing windows.

You can use more south-facing glass in a house with a lot of mass. Mass is provided by the building materials used inside your home - brick finishes have more mass than drywall, for example. Mass stores the added solar energy from the larger windows, which would otherwise cause daytime overheating, and releases it at night to offset the windows' higher heat loss. As an example, you could double the optimum area of south-facing glass if you quadrupled the mass, but this would be very expensive (see the section on heat storage).

You need less south-facing glass in a more energy efficient home. By contrast, you can install more south-facing glass if you use windows with more glazings. In an energy efficient Alberta home of standard mass, for example, the optimum area of triple-pane solar glass ranges between 12 and 15 per cent of the floor area. The percentage would be lower for double-pane windows. In a super energy efficient home with very high levels of insulation, the optimum area for both double and triple is much lower. Remember that you will always have a lower heating bill with triple-pane windows because they have superior net heat gains.

Going above or below a range of optimum area means spending more to heat your home. If you have less than optimal glazing, you are not taking full advantage of the sun; more than optimal glazing means higher night-time heat losses (and more daytime overheating). Variation in heating costs within the range of optimum area is very small. If you keep to the low end of the range, you will get less overheating and spend less on building materials. Area for area, walls cost less than windows.

Shading solar-facing windows. The paths of the sun across the sky from season to season affect the way you design for the sun and the way you design for shade. Shading devices should block the summer sun but not the winter sun. Fixed overhangs provide seasonal shade because sun angles vary from summer to winter. On December 21, the day the sun's path is lowest in the sky, the sun is between 10 and 20 degrees above the southern horizon at noon for most of Alberta. On June 21, the day the sun's path is highest in the sky, it is between 55 and 65 degrees. As Table 2 shows, sun angles decrease and increase symmetrically on either side of these dates; the sun angles are the same on February 21 and October 21, for example.

To design an overhang, decide when you want complete sun, complete shade, and partial shade. If you want very little sun in the summer, you may choose to completely shade large south-facing windows at noon for two months (from May 21 to July 21). For a sunnier and hotter house, you may want only half shade on June 21. Figure 7 shows how sun angles are used in conjunction with these decisions to determine an overhang length.

The best way to design an overhang is with a sunpath diagram. This is a graph that plots the location of the sun - both its altitude and its angle off true south - for any day of the year at any time of day. The Energy Conservation Branch has sunpath diagrams for eight loca-

tions in the province available on request. Call the Energy Matters inquiry line by dialing zero and asking for Zenith 22339 (call 427-5300 in Edmonton).

Table 2
Sun angles above the south horizon at solar noon (in degrees)

	Lethbridge (49 40'N)	Calgary (51 06'N)	Red Deer (52 10'N)	Edmonton (53 30'N)	Ft. McMurray (56 40'N)
Dec 21	17	15	14	13	10
Jan 21	20	18	17	16	13
Feb 21	29	27	26	25	22
Mar 21	41	39	38	37	34
Apr 21	52	50	49	48	45
May 21	60	58	57	56	53
Jun 21	64	62	61	60	57
July 21	60	58	57	56	53
Aug 21	52	50	49	48	45
Sep 21	41	39	38	37	34
Oct 21	29	27	26	25	22
Nov 21	20	18	17	16	13

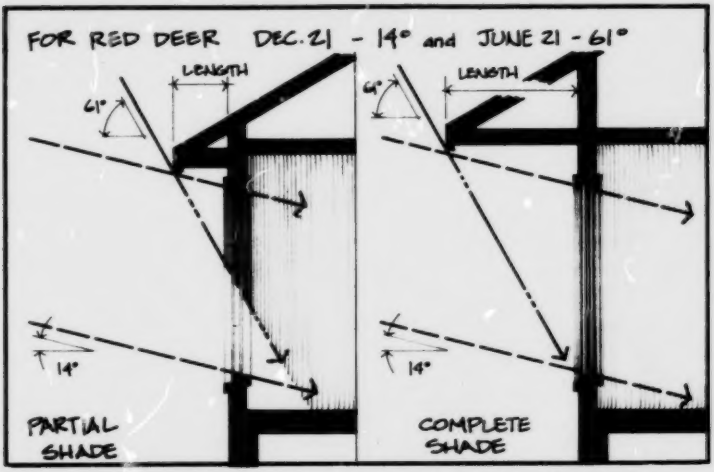

Figure 7 Sun angles and seasonal shade affect the design of fixed overhangs.

Remember that decisions about sunlight and shade for one season will affect sunlight and shade in another. For example, if you choose to have complete sun on your south-facing windows until March 21, when the weather can still be cool, it means you will have complete sun starting on September 21, when the weather can still be warm. Fixed overhangs are not adjustable for cool springs and warm falls; the sun's height in the sky, not the outside temperature, determines the amount of light and shade. For this reason, some designers prefer movable shading such as awnings and curtains, or shade from deciduous trees and vines whose leaves block the sun during the summer and fall. These options, however, have their own complications: somebody has to take the time and care to operate awnings, and leafless deciduous trees can still block up to 50 per cent of the winter sun.

Slope for solar-facing windows. Sun angles also affect the best slope for solar-facing windows. During the heating season in Alberta, when the sun is low on the horizon, a window tilted 10 to 20 degrees off vertical will let in a little more light than a vertical window. This is because the sloped window is perpendicular to the sun's rays and so reflects slightly less light. Sloped windows, however, are more difficult to install and seal well, and are more exposed to rain and dirt. You must also use tempered glass, which is more expensive, if a window is tilted more than 15 degrees off vertical.

Heat Distribution

Good air circulation is key to distributing heat in a passive solar home. Air of different temperatures tends to stratify in a home; warm air collects in higher spaces near the ceiling or upstairs (vertical stratification) and toward the solar side of the house (horizontal stratification). Circulating this warm air to mix with the cooler air below and behind it will make best use of the heat and improve the comfort of your home. You can encourage air circulation in the physical layout of your home or sunspace, and in the design of your heating and ventilating systems.

Improving Natural Convection

If you are building a new home or extensively renovating an old one, consider an open concept floor plan. Open floor plans allow air to circulate more freely than plans divided into many separate rooms. Unobstructed, air will circulate through a passively heated home because of natural convection. You can also circulate air with the help of fans.

In summer, encourage good air circulation and ventilation by taking advantage of prevailing summer winds. Have some windows that open into the wind (on the windward side of your house) and more that open away from the wind (on the leeward side). Wind creates negative pressure on the leeward side, drawing air out and allowing air from the windward side to move in. Casement windows (that open and close like doors) are a good option; they can scoop breezes into your home on the windward side and they seal better than other kinds of operable windows. Locating operable windows in both the upper and lower floors of your home also has an advantage for summer cooling; at night, warm air can escape through upper-storey windows and draw cool air through lower windows.

Fan-Forced Heat Distribution

Figures 8 and 9 illustrate how to design your heating and ventilating systems to improve air circulation. If you have a forced-air heating system, put the return air ducts high in a solar-heated space to skim warm air off the ceiling and reduce stratification. If you have radiant heating, your centralized ventilation system can help circulate air. (We assume a passive solar home is an energy efficient home that will therefore have centralized ventilation to maintain good indoor air quality). Put the exhaust ducts of the ventilation system far enough away from solar-heated spaces to pull warm air to other parts of your home. Ceiling fans in rooms with high ceilings and fans between rooms can also help reduce vertical and horizontal stratification.

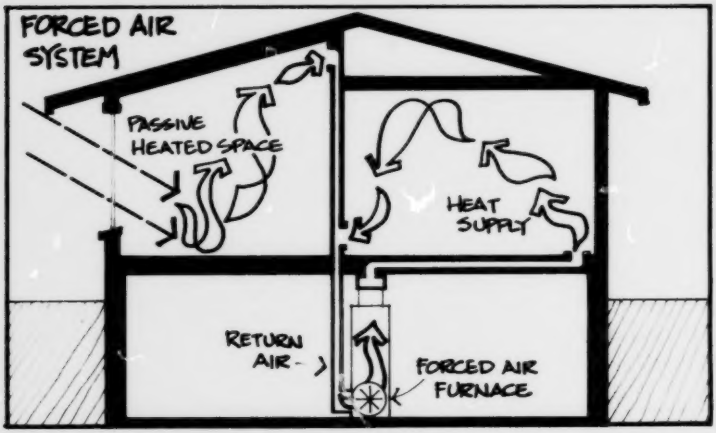

Figure 8 Forced-air heating systems can be used to encourage air circulation.

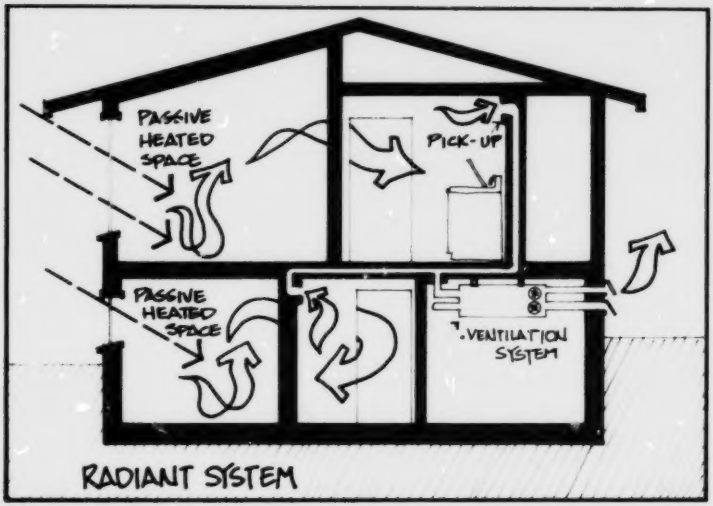

Figure 9 Radiant systems require a separate ventilation system to circulate air.

When choosing a heating system for a new home, remember that the fans on forced-air systems are much more powerful than ventilation fans or room fans; their continous low-speed circulation rate is typically 250 to 300 litres per second (500 to 600 cubic feet per minute) compared to about 50 litres per second (100 cubic feet per minute) for a ventilation or room fan. This makes passive solar design and forced-air heating a good combination.

Heat Storage

Storing heat becomes important when you have a lot of south-facing glass but do not want large day-to-night temperature swings. Unless properly designed, an overglazed space will severely overheat during the day and cool down too much at night. Big temperature swings can be uncomfortable for people living in a passive solar house and fatal to greenhouse plants. If a solar-heated space is not a permanent home for either people or plants - such as a self-contained recreational sunspace - large temperature swing may be acceptable.

A home with too much glass overheats because it receives more solar energy than it can store. You can correct this problem simply by exhausting the heat from your house, but this means you cannot

use the heat later when the house cools down. The other solution is to increase the capacity of your home to store energy by adding **thermal mass.** Concrete, brick, stone, ceramic tile, water and extra drywall are commonly used for thermal mass. They reduce temperature swings because they can absorb a large amount of heat when their surroundings are hot and release it when the sun sets and their surroundings cool. Excess heat during the day is thus available for use at night.

While increasing the area of south-facing windows and adding a lot of mass results in a lower utility bill, the benefit is small compared to the expense. You will spend more money on windows and building materials to trim a heating bill that is already small - $200 a year for a typical energy efficient home in Alberta. Boosting glass area and mass does not have a good payback, but it may make sense if you want more south-facing windows for other reasons such as daylight or a nice view.

Properties of Thermal Mass

Good thermal mass can absorb heat quickly and store a lot of heat. Stated more technically, good thermal mass should have high thermal conductivity and high specific heat capacity.

A substance with high thermal conductivity can transport heat away from its surface quickly. This means it can absorb incoming energy rather than overheating at its surface. The same property allows it to radiate heat quickly when the temperature of its environment drops. The higher the specific heat capacity of a material, the more heat it can hold. This means you need less of a substance with a high specific heat capacity to control temperature swings in a passive solar space. Water holds a lot more heat per kilogram than almost any other material, but is more difficult to use in a living space than solid mass.

Color and finishing materials have an effect on the performance of thermal mass. Dark-colored, dull-finished mass absorbs sunlight better than shiny light-colored mass. Tile and paint are better finishes than carpet or wood because they do not insulate the mass from its environment.

Location of Thermal Mass

The best place to put thermal mass is in a space directly heated by the sun. You can put mass outside the space as long as you install some method of moving solar-heated air to it - usually an air duct with fans. Without a thermal link, heavy materials outside the passive solar space will have little effect on a home's performance. In a house where the basement is not a direct gain space, for example, there is little advantage in choosing a concrete basement over a wood basement.

In a direct gain space, thermal mass works best if it is distributed evenly. At our latitudes, a vertical mass is better than a horizontal one - a heavy wall is better than a heavy floor - because the sun is too low on the horizon during the heating season to have good access to a floor (unless the windows extend close to the floor). If the mass is spread over a large area - for example, if extra drywall on the ceiling and walls is used - it is best to diffuse sunlight over as large an area as possible. You can diffuse light by bouncing it off light-colored surfaces where it enters a room. As much as possible, light-weight objects such as furniture and wood-framed walls should be kept a light colour to help diffuse light and keep these objects from overheating during the day. Light-colored furniture fabrics will also fade less.

If you want to avoid thermal mass in a direct gain space, you can use remote storage or mass that is separate from the space. Figure 10 illustrates the difference between direct gain mass and remote storage. To be a passive solar design, the thermal link between remote storage and a solar-heated space should be part of an existing air distribution system. For example, a remote storage mass could be a bin of rocks in the basement (or a room full of containers of water) connected to a return air duct on a forced-air heating system. Air from the solar-heated space would travel through this bin and leave or pick up heat on its way. Remote storage should be insulated from the rest of the house because this allows greater control over the release of heat from the mass.

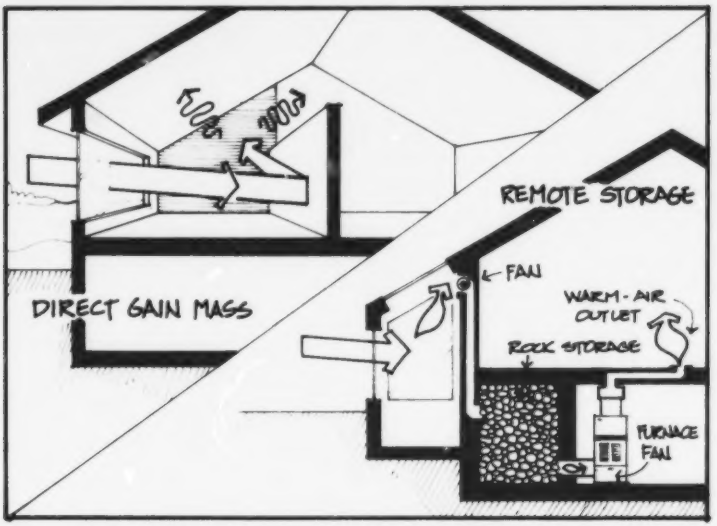

Figure 10 Options for storing heat from passive solar gain.

Two Examples of Passive Solar Design

This section shows how the rules of thumb for passive solar design in Alberta apply to two examples: a new home and a sunspace added to an existing home both at about 53 degrees north latitude. The examples illustrate problem-solving in the design process and the consequences of following or ignoring rules of thumb.

Designing a New Home for Passive Solar

If you are planning to build a new home, you usually start with some preferences about size, location, general appearance and other features. For example, consider a house for a family of four building in a new subdivision. They want their house to look conventional and to operate with few demands on their time and attention. In the area where they plan to build, there is a good view of a ravine to the southwest. The family enjoys a lot of sunlight and is interested in making good use of passive solar heating in their new home.

To optimize passive solar heating, the house will have to be energy efficient. It will be well-sealed with centralized ventilation and well-insulated with an RSI 7 (R 40) ceiling, RSI 5.25 (R 30) walls, and an RSI 3.5 (R 20) basement.

The next step is to choose a suitable house plan and then to decide on heating system, orientation, siting and window design (and thermal storage if necessary).

House plan

Figures 11, 12 and 13 show a house plan that meets many of the family's criteria. It looks conventional from the outside - in particular, the amount of glass is not overwhelming - and allows lots of natural light. The design suits an urban lot because it is narrow and gives access to the garage from the street, a useful detail since many new subdivisions are built without alleys. Its passive solar features include:

- **a solar side.** Windows are concentrated on one side of the house to allow good access to the sun. Locating few windows in other orientations also helps control heat losses. The solar-facing window area is about 12 per cent of the floor area, within the optimal range for a standard mass house with triple glazing.

- **buffer zones.** On the non-solar side, the house is protected from winter winds by a garage. Spaces not used for living - such as the bathrooms - also act as buffers on the non-solar side.

- **an open floor plan.** The cathedral ceiling over the living room helps air to circulate between floors. Except for the bedrooms where privacy is important, there are no doors and few walls between rooms and this allows free air movement.

Figure 11 South elevation of example house.

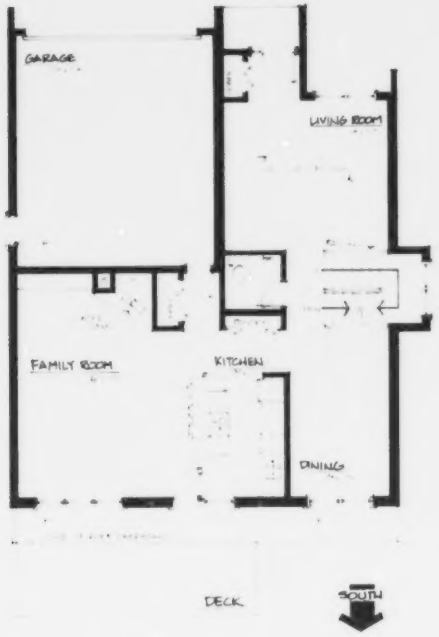

Figure 12 Main floor plan of example house.

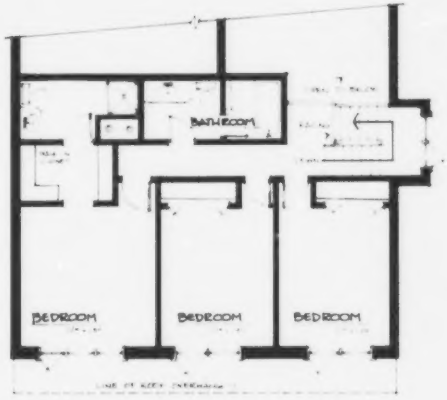

Figure 13 Second floor plan of example house.

Heating system
You usually choose your heating system early in the design process so that you can plan where the ducts, pipes or space heaters go. We have chosen a forced-air natural gas furnace with a two-speed fan for this home because it circulates air well. If our house had radiant heating, we would want to install fans to help circulate air, particularly in the cathedral ceiling.

The return air ducts of the heating system are installed high in rooms to skim solar-heated air off the ceiling where it will collect.

Orientation
The best orientation for the solar side of the house would be south, but we are going to face the solar side southwest to take advantage of the good view. Because the solar side is the back of the house, we have chosen a lot that faces the street in a northeast direction. (See Figure 3. The lot labelled "A" is our choice). If you want to face your home in a particular direction in a subdivision, it is best to buy a lot oriented the correct way. With setback requirements and sidelot restrictions, it is easier to place a house square on a lot than to skew it.

If the solar side of the house were facing south, it would need about 86 gigajoules (GJ) of natural gas to heat each year. This heating requirement does not increase when we turn the house southwest, although we might expect it to. This is because the window over the stairwell, which faces east when the solar side faces south, becomes a southeast window when we turn the house, and its solar contribution goes up. If we face the solar side due west, the house needs 97 GJ per year of energy, an increase of 13 per cent in heating costs.

With its solar side facing southwest, our house will be more prone to overheating. It will require particular attention to window shading and possibly more ventilation in the late spring and early fall when temperatures are warm but sun angles for the southwest sun are low.

Siting
The house should be placed on the lot to prevent shading of its solar side by the neighboring house to the east. By pointing the solar side 45 degrees west of south, some of the prime morning hours are already lost during part of the heating season. Shading on the east would only interrupt them more.

The lot can be landscaped to enhance the performance of the house. Deciduous trees on the west corner of the lot will help shade the windows in the summer from the setting sun, while allowing the winter sun to penetrate. The garage acts as a buffer protecting the house from the northwest winter winds. An extra windbreak of conifer trees at the northwest corner could cause snowdrifts across the driveway (Figure 14).

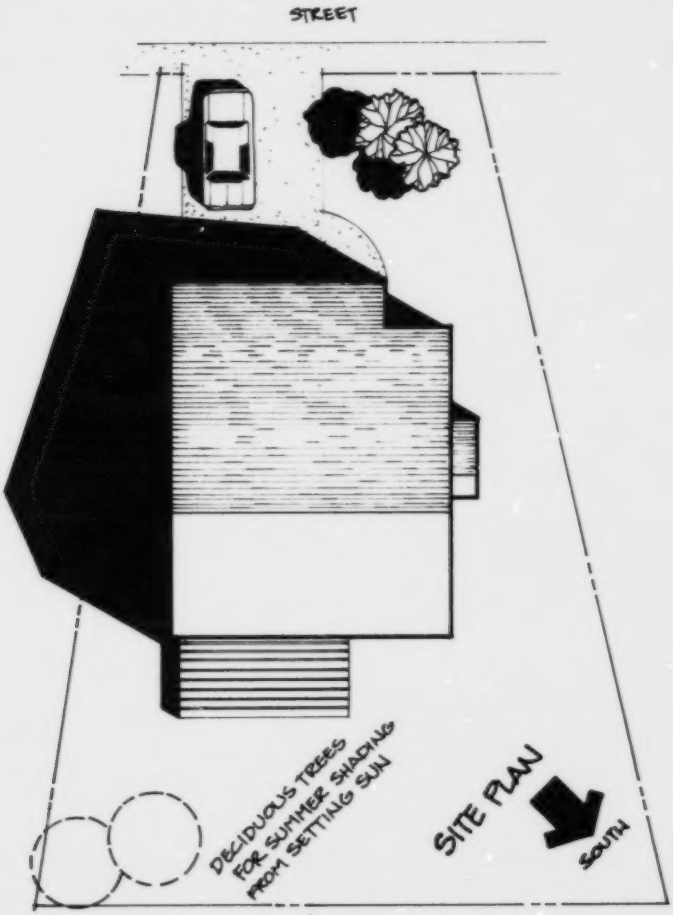

Figure 14 Site plan.

Window design

All windows in the house are triple-glazed to control condensation and heat losses. The heating bill for a home with triple glazing is lower than for a home with double glazing. The house can also have a larger area of triple-pane glass than double-pane glass without a penalty in heat losses. This allows the family more sunlight and a better view of the ravine.

Since the basement is not a direct-gain space, only the main and upper floors are counted when calculating solar-facing window area. These floors have a total area of 195 square metres (2100 square feet). The southwest windows are 23.4 square metres (252 square feet) for a glass-to-floor-area ratio of 12 per cent. The house is on the low end of the optimum range of solar-facing window area for its mass and energy efficiency. This is one precaution we have taken to control overheating. As mentioned, the house is already more susceptible to overheating because it faces southwest. Staying within the optimal range also saves the family money: they do not have to spend a lot on extra glass or thermal storage.

The southwest windows are shaded with a fixed overhang. Using the principles described earlier in Figure 7, Figure 15 shows how the length was determined to give complete shade at noon on June 21. A fixed overhang does not give ideal shading for our house because it faces southwest; the sun can still beat directly in the windows when it is in the southwest quadrant and low on the horizon. The overhang would have to be impractically long to shade the windows from the southwest sun. Movable window shading, such as shutters,

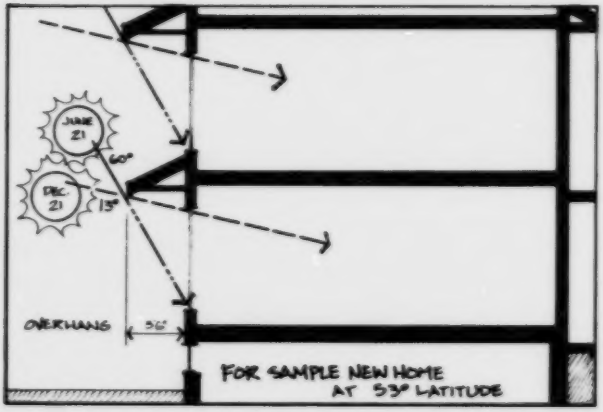

Figure 15 Determining the length of the overhangs.

would be a better solution but the family wants a house that requires little supervision. The deciduous trees on the west corner of the lot are a crucial element in shading the solar-facing windows.

We have chosen operable windows to take advantage of prevailing summer winds in the west. This is another measure that will help relieve overheating. The southeast window over the stairwell opens to help draw air out. On the southwest side, there are operable casement windows on both floors to let breezes in and to encourage air movement between floors. The windows are hinged on their southeast side so that they open to scoop wind into the house.

Our house does not have insulated shutters because of the added demands it makes on the homeowner's time and attention. Insulated shutters, however, would make a substantial difference to the performance of the house. On our triple-pane windows, RSI 0.8 (R-5) shutters would reduce the annual use of natural gas by about 16 GJ or almost 13 per cent.

Summary

This family wanted a conventional house that took advantage of passive solar heating. We started with an energy efficient house and incorporated features such as: large windows on the southwest to give access to the sun and the view; an open floor plan and a forced-air heating system to encourage air circulation; and fixed overhangs and deciduous trees to reduce overheating. Our house is an example of a balanced design. It meets many priorities including attention to passive solar features, and to esthetics, comfort and lifestyle.

Designing a Sunspace

Before you design a sunspace, you have to know what it is for. Do you plan to garden in it? Do you want to heat your home with it? Do you want to use it for recreation? In this example, we will assume that the owners of an existing house want to add a sunspace for year-round use as a sitting area. They would like to use whatever heat they can from it, but are not concerned about making the sunspace an important heat source for their home. They would like to keep some house plants in the space. Their house faces south-southeast and has a forced-air gas furnace.

Floor plan

Figure 16 shows a simple design. The sunspace is about three metres by five metres (ten feet by 17 feet) - big enough to seat four or five people comfortably. The floor is at ground level, below the main floor of the house, to give it added head room.

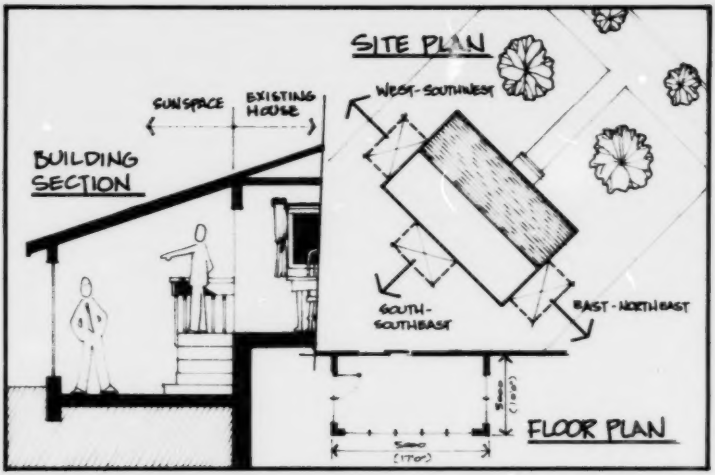

Figure 16 Example sunspace

The sunspace shares one of its walls with the house and a patio door connects them. The door allows the sunspace to be completely closed off from the house. The long exterior wall has 9.75 square metres of glass (105 square feet). One of the short walls has window area totalling about four square metres (42 square feet); the other has a patio door to the outside with 3.8 square metres of glass (41 square feet). Each of these window areas by itself far exceeds the optimum glazing levels for the space, but creates the bright environment that the owners want.

The ceiling of the space is insulated to RSI 7 (R 40) and the walls to RSI 5.25 (R 30).

Orientation

As Figure 16 illustrates, the sunspace can face one of three directions and still get the winter sun: south-southeast, west-southwest or east-northeast. The difference among these orientations for solar gains is neglible. Solar contributes about 17 per cent of the heat required by the space in all cases. This is probably because even the smallest of the three window areas, at 24 per cent of the floor area, can overheat the space. We will choose the south-southeast orientation because it will give the space good sunlight all day and because it will orient most windows south where they can be more effectively shaded with a fixed overhang.

Window design
All the windows are triple-pane to control heat losses and condensation. Substituting double-pane windows for triple-pane would more than double the amount of natural gas needed to heat the space - from 11 GJ to 23 GJ per year, assuming an average temperature of 21 degrees centigrade (70 degrees farenheit) and a day-to-night temperature swing of 5.5 degrees centigrade (10 degrees farenheit).

The south-southeast windows are shaded with a 1.2 metre (four foot) overhang. This length is generally considered a maximum by designers. Anything longer cuts off too much view and looks awkward. The overhang will not prevent the space from overheating, but it will help.

Putting operable windows in the sunspace will help remove overheated air in summer (in winter, the owners will use this heat in their house). Casement windows are used because they seal well and scoop breezes better. Assuming prevailing summer winds are from the west, the best ventilation will occur with an operable window on the east-northeast side (the leeward side) and the west-southwest side (the windward side). On the south-southwest side, windows should be hinged on their east side to catch the wind.

Thermal mass
Since the space has so much glass, the question of whether to add thermal mass becomes an issue. We would have to add a lot of thermal mass to this space to reduce temperature swings. We could add it cheaply in the form of water-filled drums, but these take up a lot of space and are not very attractive. Other types of mass - brick, gravel pads under the floor - are expensive, especially since large temperature swings are acceptable because the space can be completely sealed off from the house by closing the connecting door. We have decided not to add thermal mass and will manage temperature swings with ventilation and heating systems.

Heating and ventilating systems
The objectives of our heating and ventilating design are to isolate the sunspace from the house when it cannot supply useful heat, but to heat the space with the main heating system when it is occupied. In our design, the space is connected to the main heating system by thermostatically controlled return and supply air ducts. The return duct is located near the ceiling. When the sunspace overheats during the winter, the ducts automatically open and the heating system fan circulates the hot air through the house. Note that this requires continuous circulation from the fan; if the furnace does not have a two-speed fan, the owners will have to install one. A wall

switch will also open the heat supply and return air ducts to ensure a comfortable temperature is maintained when the space is occupied. A thermostatically controlled 1500 watt electric space heater, kept at a low setting, will keep the space from freezing during winter nights. When the sunspace overheats in summer, it is ventilated directly to the outside by a thermostatically controlled fan (Figure 17).

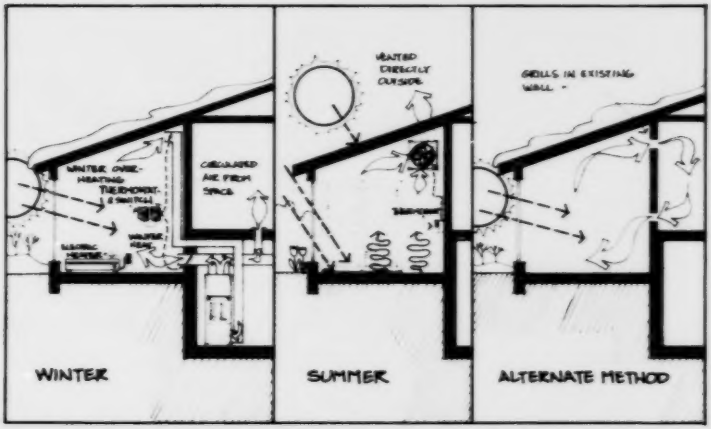

Figure 17 Possible heating and ventilating system design for the sunspace.

Heat could also be transferred to the house through vents in the connecting wall that would allow natural convection to circulate air. This would be a more difficult renovation because it would require more holes in the wall. It would also be a less effective and controllable way of ventilating the sunspace when it overheats.

Summary

We have designed this sunspace primarily as a recreational area and to take advantage of solar energy. Its key features are: an orientation that gives it light all day; triple-glazed windows that keep heat losses as low as possible; and a heating and ventilating system that provides heat to the home when possible and takes heat only when necessary. This design makes the sunspace a bright, affordable addition to the home and causes only a small increase in heating costs.

Summary

The rules of thumb we have described in this booklet apply to direct gain passive solar heating in Alberta. These rules should bend to accommodate your needs and tastes. Each time you alter a rule, however, you alter the balance of elements that makes passive solar work. A correct balance is crucial to comfortable, usable passive solar heating. Designing balance into your house requires skill and experience. Many architects and designers now use computer modelling to analyse the detailed dynamics of passive solar heating.

Passive solar features can be a real benefit to your home. They are simple and affordable, they reduce heating costs, and they help to make your home a bright, comfortable and pleasant place to live.